Chapter 6
Human Systems Integration (HSI)

6.0. Overview

DoD acquisition policy requires optimizing total system performance and minimizing the cost of ownership through a "total system approach" to acquisition management (see DoD Directive 5000.1).

6.0.1. Purpose

While Chapter 4 discusses systems engineering at large, this chapter specifically addresses the human systems elements of the systems engineering process. This chapter provides the Program Manager with the necessary background and understanding to design and develop systems that effectively and affordably integrate with human capabilities and limitations, it makes the PM aware of the staff resources available to assist in this endeavor.

6.0.2. Contents

This chapter has six main sections. Section 6.1 briefly reviews the total systems approach directed by DoD Directive 5000.1. Section 6.2 describes each of the domains of Human Systems Integration: Manpower, Personnel, Training, Human Factors, Safety and Occupational Health, Personnel Survivability, and Habitability. Each of these sub-sections contains an overview of the domain, addresses domain requirements, and ends with a discussion of planning considerations, with one exception. Section 6.3 stands alone to provide extensive discussion and planning details for the Human Factors Engineering domain. Section 6.4 then follows with the implementation of HSI, to include formulation of the HSI strategy and the sequencing of expected HSI activities along the timeline of the Defense Acquisition Framework. Section 6.5 describes the human considerations associated with resource estimating and planning; it is the HSI complement to Chapter 3. The last section, Section 6.6, provides two reference listings for additional information.

6.1. Total System Approach

The total system includes not only the prime mission equipment, but also the people who operate, maintain, and support the system; the training and training devices; and the operational and support infrastructure. Human Systems Integration (HSI) analysts assist PMs by focusing attention on the human part of the system and by integrating and inserting manpower, personnel, training, human factors, safety, occupational health, habitability, and personnel survivability considerations into the Defense acquisition process. Consistent with DoD Instruction 5000.2, when addressing HSI, the PM must focus on each of the "domains" of HSI.

6.2. Human Systems Integration Domains

6.2.1. Manpower

6.2.1.1. Manpower Overview

Manpower factors are those job tasks, operation/maintenance rates, associated workload, and operational conditions (e.g., risk of hostile fire) that are used to determine the number and mix of military and DoD civilian manpower and contract support necessary to operate, maintain, support, and provide training for the system. Manpower officials contribute to the Defense acquisition process by ensuring that the PM pursues engineering designs that optimize manpower and keep human resource costs at affordable levels (i.e., consistent with strategic manpower plans). Technology approaches and solutions used to reduce manpower requirements and control life-cycle costs should be identified in the capabilities documents early in the process. For example, material-handling equipment can be used to reduce labor-intensive material-handling operations and embedded training can be used to reduce the number of instructors.

6.2.1.2. Manpower Parameters/Requirements

DoD Directive 5000.1 directs the DoD Components to plan programs based on realistic projections of the dollars and manpower likely to be available in future years. Manpower goals and parameters should be based on manpower studies and analysis. They should ensure that design options that reduce workload and ensure program affordability are pursued, and that lower-priority design features do not take precedence. Throughout the system life cycle, they should keep ownership costs and manpower at desired levels. And they should preserve future-year resources desinated for other higher priority programs (i.e., not required later, additional funding)

When there are Congressional or Administrative caps placed on military end strength, the introduction of a new system or capability will require compensating reductions (trade-offs) elsewhere in the force structure or in the Individuals Account. Manpower officials should identify areas for offsets, or “bill-payers,” for the new system and establish constraints based on available resources. If the new system replaces a system in the inventory, manpower officials should determine whether the constraints placed on the predecessor system also apply to the new system. They should consider the priority of the new system and determine if either additional resources will be provided or more stringent constraints will apply. Manpower authorities should consider the availability of resources over the life of the program and weigh competing priorities when establishing manpower constraints for acquisition programs. Reviews should consider all military and civilian manpower and contract support needed to operate, maintain, support, and provide training for the system over the entire life of the program.

Manpower can be a major determinant of program cost and affordability. The Initial Capabilities Document (ICD) should identify any manpower constraints that, if exceeded, would require the Department to reconsider the utility of the program. The ICD should specify the expected location of the system on the battlefield and the expected operational conditions (e.g., a high [or low] likelihood of hostile fire or collateral damage). These specifications affect early cost, manpower mix, training, personnel, and survivability requirements.

The Capability Development Document (CDD) should establish manpower parameters (objectives and thresholds) consistent with existing departmental constraints. If the program is manpower intensive, it may be prudent to establish a manpower key performance parameter (KPP) early in the acquisition process. Setting a KPP will ensure the system fits within manpower parameters established by the Department, that agreed-upon resource thresholds are not exceeded, and that the system will not require additional resources from higher priority programs later in the acquisition process. A KPP should only be established if the adverse manpower effect of exceeding the KPP outweighs the overall benefits of the new capability. In all cases, manpower constraints and KPPs must be defendable and commensurate with the priority and utility of the new capability.

The CDD should also address specific, scenario-based, factors that affect manpower, such as surge requirements, environmental conditions (e.g., arctic or desert conditions), and expected duration of the conflict. These factors are capability-related and directly affect the ability of the commander to sustain operations in a protracted conflict.

6.2.1.3. Manpower Planning

Manpower analysts determine the number of people required, authorized, and available to operate, maintain, support, and provide training for the system. Manpower requirements are based on the range of operations during peacetime, low intensity conflict, and wartime. They should consider continuous, sustained operations and required surge capability. The resulting Manpower Estimate accounts for all military (Active Reserve, and Guard), DoD civilian (U.S. and foreign national), and contract support manpower.

DoD Instruction 5000.2 requires the PM to work with the manpower community to determine the most efficient and cost-effective mix of DoD manpower and contract support, and identify any issues (e.g., resource shortfalls) that could impact the PM's ability to execute the program. Generally, the decision to use DoD civilians and contract labor in theater during a conflict where there is a high likelihood of hostile fire or collateral damage is made on an exception basis. In all cases, risk reduction shall take precedence over cost savings. Additionally, the PM shall consult with the manpower community in advance of contracting for operational support services to ensure that sufficient workload is retained in-house to adequately provide for career progression, sea-to-shore and overseas rotation, and combat augmentation. The PM should also ensure that inherently governmental and exempted commercial functions are not contracted. These determinations shall be based on the Manpower Mix Criteria.

Consistent with sections E1.4 and E1.29 of DoD Directive 5000.1, the PM must evaluate the manpower required and/or available to support a new system and consider manpower constraints when establishing contract specifications to ensure that the human resource demands of the system do not exceed the projected supply. The assessment must determine whether the new system will require a higher, lower, or equal number of personnel than the predecessor system, and whether the distribution of ranks/grade will change. Critical manpower constraints must be identified in the ICD and CDD to ensure that manpower requirements remain within DoD Component end-strength constraints. If sufficient end-strength is not available, a request for an increase in authorizations should be submitted and approved as part of the trade-off process.

When assessing manpower, the system designers should look at labor-intensive (high-driver) tasks. These tasks might result from hardware or software interface design problems. These high-driver tasks can sometimes be eliminated during engineering design by increasing equipment or software performance. Based on a top-down functional analysis, an assessment should be conducted to determine which functions should be automated, eliminated, consolidated, or simplified to keep the manpower numbers within constraints.

Manpower requirements should be based on task analyses that are conducted during the functional allocation process and consider all factors including fatigue; cognitive, physical, sensory overload; environmental conditions (e.g., heat/cold), and reduced visibility. Additionally, manpower must be considered in conjunction with personnel capabilities, training, and human factors engineering trade-offs.

Tasks and workload for individual systems, systems-of-systems, and families-of-systems should be reviewed together to identify commonalities, merge operations, and avoid duplication. The cumulative effects of system-of-system, family-of-systems and related system integration should be considered when developing manpower estimates.

When reviewing support activities, the PM should work with manpower and functional representatives to identify process improvements, design options, or other initiatives to reduce manpower, improve the efficiency or effectiveness of support services, or enhance the cross-functional integration of support activities.

The support strategy should document the approach used to provide for the most efficient and cost-effective mix of manpower and contract support and identify any cost, schedule, or performance issues, uncompleted studies that could impact the PM's ability to execute the program.

6.2.2. Personnel

6.2.2.1. Personnel Overview

Personnel factors are those human aptitudes (i.e., cognitive, physical, and sensory capabilities), knowledge, skills, abilities, and experience levels that are needed to properly perform job tasks. Personnel factors are used to develop the military occupational specialties (or equivalent DoD Component personnel system classifications) and civilian job series of system operators, maintainers, trainers, and support personnel. Personnel officials contribute to the Defense acquisition process by ensuring that the PM pursues engineering designs that minimize personnel requirements, and keep the human aptitudes necessary for operation and maintenance of the equipment at levels consistent with what will be available in the user population at the time the system is fielded.

6.2.2.2. Personnel Parameters/Requirements

DoD Instruction 5000.2 requires the PM to work with the personnel community to define the performance characteristics of the user population, or "target audience," early in the acquisition process. The PM should work with the personnel community to establish a Target Audience Description (TAD) that identifies the cognitive, physical, and sensory abilities—i.e., capabilities and limitations, of the operators, maintainers, and support personnel that are expected to be in place at the time the system is fielded. When establishing the TAD, HSI analysts should verify whether there are any recruitment or retention trends that could significantly alter the characteristics of the user population over the life of the system. Additionally, HSI analysts should consult with the personnel community and verify whether there are new personnel policies that could significantly alter the scope of the user population (e.g., policy changes governing women in combat significantly changed the anthropometric requirements for occupational specialties).

Per DoD Instruction 5000.2, to the extent possible, systems shall not be designed to require cognitive, physical, or sensory skills beyond those found in the specified user population. During functional analysis and allocation, tasks should be allocated to the human component consistent with the human attributes—i.e., capabilities and limitations, of the user population to ensure compatibility, interoperability, and integration of all functional and physical interfaces. Personnel requirements should be established consistent with the knowledge, skills, and abilities (KSAs) of the user population that is expected to be in place at the time the system is fielded and over the life of the program. Personnel requirements are usually stated as a percentage of the population. For example, the CDD might require "physically accommodating the central 90% of the target audience." Setting specific, quantifiable, personnel requirements in the CDD assists establishment of test criterion in the TEMP.

6.2.2.3. Personnel Planning

Personnel capabilities are normally reflected as knowledge, skills, abilities (KSAs), and other characteristics. The availability of personnel and their KSAs should be identified early in the acquisition process. The DoD Components have a limited inventory of personnel available, each with a finite set of cognitive and psychomotor abilities. This could affect specific system thresholds.

The PM should use the target audience description (TAD) as a baseline for personnel requirements assessment. The TAD should include information such as inventory; force structure; standards of grade authorizations; personnel classification (e.g., MOS/NEC) description; biographical information; anthropometric data; physical qualifications; aptitude descriptions as measured by the Armed Forces Vocational Aptitude Battery (ASVAB)); task performance information; skill grade authorization; physical profile (PULHES); security clearance; and reading grade level.

The PM should assess and compare the cognitive and physical demands of the projected system against the projected personnel supply. The PM should also determine the physical limitations of the target audience (e.g., color vision, acuity, and hearing). The PM should identify and shortfalls highlighted by these studies.

The PM should determine if the new system contains any aptitude-sensitive critical tasks. If so, the PM should determine if it is likely that personnel in the target audience can perform the critical tasks of the job.

The PM should consider personnel factors such as availability, recruitment, skill identifiers, promotion, and assignment. He/She should consider the impact on recruiting, retention, promotions, and career progression when establishing program costs, and should assess these factors during trade-off analyses.

The PM should use a truly representative sample of the target population during T&E to get an accurate measure of system performance. A representative sample during T&E will help identify aptitude constraints that affect system use.

Individual system and platform personnel requirements should be developed in close collaboration with related systems throughout the Department and in various phases of the acquisition process to identify commonalities, merge requirements, and avoid duplication. The PM should consider the cumulative effects of system-of-systems, family-of-systems, and related systems integration in the development of personnel requirements

Consistent with DoD Instruction 5000.2, Enclosure 7, the PM must summarize major personnel initiatives that are necessary to achieve readiness or rotation objectives or to reduce manpower or training costs, when developing the acquisition strategy. The acquisition and support strategy must address modifications to the knowledge, skills, and abilities of military occupational specialties for system operators, maintainers, or support personnel if the modifications have cost or schedule issues that could adversely impact program execution. The PM should also address actions to combine, modify, or establish new military occupational specialties or additional skill indicators, or issues relating to hard-to-fill occupations if they impact the PM's ability to execute the program.

6.2.3. Training

6.2.3.1. Training Overview

Training is the learning process by which personnel individually or collectively acquire or enhance predetermined job-relevant knowledge, skills, and abilities by developing their cognitive, physical, sensory, and team dynamic abilities. The "training/instructional system" integrates training concepts and strategies and elements of logistic support to satisfy personnel performance levels required to operate, maintain, and support the systems. It includes the "tools" used to provide learning experiences such as computer-based interactive courseware, simulators, and actual equipment (including embedded training capabilities on actual equipment), job performance aids, and Interactive Electronic Technical Manuals.

6.2.3.2. Training Parameters/Requirements

When developing the training/instructional system, the PM should employ transformational training concepts, strategies, and tools such as computer based and interactive courseware, simulators, and embedded training consistent with the strategy, goals and objectives of the Training Transformation Strategic Plan (March 1, 2002) and the Training Transformation Implementation Plan and Appendix 1 (June 2004).

The Department's vision for Training Transformation is to provide dynamic, capabilities-based training in support of national security requirements across the full spectrum of Service, joint, interagency, intergovernmental, and multinational operations. This new approach emphasizes the mission requirements of the combatant commanders (COCOM). The COCOM is the customer. The intent is to design systems and structure acquisition programs focused on the training needs of the COCOM. The desired outcome is to fully support COCOM requirements, missions, and capabilities, while preserving the ability of the DoD Components to train for their core competencies. The Under Secretary of Defense for Personnel and Readiness, as a member of the Defense Acquisition Board, assesses the ability of the acquisition program to support the Military Departments, COCOMs, and DoD Components.

"Training," in this context, includes training, education, and job-performance aiding. Joint training must be able to support a broad range of roles and responsibilities in military, multinational, interagency, and intergovernmental contexts, and the Department of Defense must provide such training to be truly flexible and operationally effective. Training readiness will be assessed and reported, not only in the traditional joint context, but also in view of this broader range of "joint" operations. Joint training and education will be recast as components of lifelong learning and made available to the Total Force—active, reserve, and DoD civilians. The Department will expand efforts to develop officers well versed in joint operational art. The interfaces between training systems and the acquisition process will be strengthened. The Under Secretary of Defense for Personnel and Readiness, as a member of the Defense Acquisition

Board, assesses an acquisition program's ability to support the Combatant Commander's and DoD Components' capabilities to provide HSI as an integral part of an acquisition program.

The PM should summarize major elements of the training plan in the Support Strategy. This should include logistics support planning for training, training equipment and training device acquisitions and installations.

A Special Note on Embedded Training. Both the sponsor and the eventual PM should give careful consideration and priority to the use of embedded training as defined in DoD Directive 1322.18: *Capabilities built into, strapped onto, or plugged into operational materiel systems to train, sustain, and enhance individual and crew skill proficiencies necessary to operate and maintain the equipment.* The sponsor's decisions to use embedded training must be made very early in the capabilities determination process so it can be reflected in the ICD. Analysis should be conducted to compare the embedded training with more traditional training media (e.g., simulator based training, traditional classroom instruction, and/or maneuver training) for consideration of a system's Total Operating Cost. The analysis should compare the costs and the impact of embedded training (e.g., training operators and maintenance personnel on site compared to off station travel to a temporary duty location for training). It should also compare the learning time and level of effectiveness (e.g., higher "kill" rates and improved maintenance times) achieved by embedded training. When making decisions about whether to rely exclusively on embedded training, analysis must be conducted to determine the timely availability of new equipment to all categories of trainees (e.g., Reserve and Active Component units or individual members). For instance, a National Guard tank battalion that stores and maintains its tanks at a central maintenance/training facility may find it more cost effective to rely on mobile simulator assets to train combat tasks rather than transporting its troops to the training facility during drill weekends. A job aid for embedded training costing and effectiveness analyses is: "A Guide for Early Embedded Training Decisions," US Army Research Institute for the Behavioral and Social Sciences Research Product 96-06.

6.2.3.3. Training Planning

This section will prepare the Program Manager to understand training capabilities as an integral part of the Joint Capabilities Integration and Development System (JCIDS) and, with assistance of the training community, translate those capabilities into system design features.

First, the JCIDS process should address joint training parameters for military (Active, Reserve, and Guard) and civilian personnel who will operate, maintain, and support the system. Training programs should employ a cost-effective solution, consisting of a blend of capabilities that use existing training programs and introduces new performance-based training innovations. This may include requirements for school and unit training, as well as new equipment training, or sustainment training. This also may include requirements for instructor and key personnel training and new equipment training teams.

Training should be considered early in the acquisition development process. Beginning with the Initial Capabilities Document (ICD) and following with the Concept Capability Development Document (CDD) training should be an integral part of system development.

The CDD should discuss training in terms of capabilities and not specific outcomes. Examples of training capabilities:

- The CDD should require that “the training capability allow for interactions between platforms or units (e.g., through advanced simulation and virtual exercises) and provide training realism to include threats (e.g., virtual and surrogate), a realistic electronic warfare environment, communications, and weapons.”
- The CDD should require that “embedded training capabilities not degrade system performance below threshold values nor degrade the maintainability or component life of the system.”
- The CDD should ensure that IOC is attained and that training capabilities are embedded and met by IOC.
- The CDD should require an embedded “performance measurement capability” to support immediate feedback to the operators/maintainers and possibly to serve as a readiness measure for the unit commander.
- The CDD should address the training logistics (e.g., requirements for new or upgrades to existing training facilities) necessary to support the training concept.

The training community should be specific in translating CDD capabilities into system requirements. They should also set training resource constraints. A couple of examples follow:

- The training community should consider whether the system be designed with “a mode of operation that allows operators to train interactively on a continuous basis, even when deployed in remote locations.”
- The training community should consider whether the system be capable of “exhibiting fault conditions for a specified set of failures to allow rehearsal of repair procedures for isolating faults” or require that the system “be capable of interconnecting with other (specific) embedded trainers in both static and employed conditions.” Or,
- The training community should consider whether “embedded training capabilities allow enhancements to live maneuver such that a realistic spectrum of threats is encountered (e.g., synthetic radar warnings generated during flight).”
- The training community should consider whether the “integrated training system be fully tested, validated, verified, and ready for training at the training base as criteria for declaring IOC.”

From the earliest stages of development and as the system matures, the PM should emphasize training requirements that enhance the user’s capabilities, improve readiness, and reduce individual and collective training costs over the life of the system. This may include requirements for expert systems, intelligent tutors, embedded diagnostics, virtual environments, and embedded training capabilities. Examples of training that enhances user’s capabilities:

- Interactive electronic technical manuals provide a training forum that can significantly reduce schoolhouse training and may require lower skill levels for maintenance personnel while actually improving their capability to maintain an operational system.
- Requirements for an embedded “just-in-time mission rehearsal capability” supported by the latest intelligence information and an integrated global training system/network that allows team training and participation in large scale mission rehearsal exercises can be used to improve readiness.

In all cases, the paramount goal of the training/instructional system should be to develop and sustain a ready, well-trained individual/unit, while giving strong consideration to options that can reduce life-cycle costs and provide positive contributions to the joint context of a system, where appropriate.

Training devices and simulators are systems that, in some cases, may qualify for their own set of HSI requirements. For instance, the training community may require the following attributes of a training simulator:

- It must accommodate "the central 90 percent of the male and female population on critical body dimensions;"
- It must not increase manpower requirements and should consider reductions in manpower requirements;
- It should considere reduced skill sets to maintain because of embedded instrumentation;
- It must be High Level Architecture compliant
- It must be Sharable Content Object Reference Model (SCORM) compliant
- It must be Test and Training Enabling Architecture (TENAneed link here) compliant
- It must use reusable simulation objects.

6.2.4. Human Factors

6.2.4.1. Human Factors Overview

Human factors are the end-user cognitive, physical, sensory, and team dynamic abilities required to perform system operational, maintenance, and support job tasks. Human factors engineers contribute to the Defense acquisition process by ensuring that the PM provides for the effective utilization of personnel by designing systems that capitalize on and do not exceed the abilities (cognitive, physical, sensory, and team dynamic) of the user population. The human factors engineering community integrates the human characteristics of the user population into the system definition, design, development, and evaluation processes to optimize human-machine performance for both operation and maintenance of the system.

Human factors engineering is primarily concerned with designing human-machine interfaces consistent with the physical, cognitive, and sensory abilities of the user population. Human-machine interfaces include:

- Functional interfaces (functions and tasks, and allocation of functions to human performance or automation);
- Informational interfaces (information and characteristics of information that provide the human with the knowledge, understanding and awareness of what is happening in the tactical environment and in the system);
- Environmental interfaces (the natural and artificial environments, environmental controls, and facility design);
- Cooperational interfaces (provisions for team performance, cooperation, collaboration, and communication among team members and with other personnel);
- Organizational interfaces (job design, management structure, command authority, policies and regulations that impact behavior);
- Operational interfaces (aspects of a system that support successful operation of the system such as procedures, documentation, workloads, job aids);

- Cognitive interfaces (decision rules, decision support systems, provision for maintaining situation awareness, mental models of the tactical environment, provisions for knowledge generation, cognitive skills and attitudes, memory aids); and,
- Physical interfaces (hardware and software elements designed to enable and facilitate effective and safe human performance such as controls, displays, workstations, worksites, accesses, labels and markings, structures, steps and ladders, handholds, maintenance provisions, etc,).

6.2.4.2. Human Factors Parameters/Requirements

Human factors requirements, objectives, and thresholds should provide for the effective utilization of personnel through the accommodation of the cognitive, physical, and sensory characteristics that directly enhance or constrain system performance.

Cognitive requirements address the human's capability to evaluate and process information. Requirements are typically stated in terms of response times and are typically established to avoid excessive cognitive workload. Operations that entail a high number of complex tasks in a short time period can result in cognitive overload and safety hazards. The CDD should specify whether there are human-in-the-loop requirements. This could include requirements for "human in control," "manual override," or "completely autonomous operations."

Physical requirements are typically stated as anthropometric (measurements of the human body), strength, and weight factors. Physical requirements are often tied to human performance, safety, and occupational health concerns. To ensure the average user can operate, maintain, and support the system, requirements should be stated in terms of the user population. For instance, when the user requires a weapon that is "one-man portable," weight thresholds and objectives should be based on strength limitations of the user population and other related factors (e.g., the weight of other gear and equipment and the operational environment). For example, it may be appropriate to require that "the system be capable of being physically maintained by the central 90 percent of the target audience when wearing standard battle dress, or arctic and MOPP IV protective garments inside the cab," or that "the crew station physically accommodate the central 90 percent of the target audience."

Sensory requirements are typically stated as visual, olfactory (smell), or hearing factors. The CDD should identify operational considerations that affect sensory processes. For example, systems may need to operate in noisy environments where weapons are being fired or on an overcast moonless night with no auxiliary illumination.

6.2.5. Safety and Occupational Health

6.2.5.1. Safety and Occupational Health Overview

Safety factors consist of those system design characteristics that serve to minimize the potential for mishaps causing death or injury to operators and maintainers or threaten the survival and/or operation of the system. Prevalent issues include factors that threaten the safe operation and/or survival of the platform; walking and working surfaces including work at heights; pressure extremes; and control of hazardous energy releases such as mechanical, electrical, fluids under pressure, ionizing or non-ionizing radiation (often referred to as "lock-out/tag-out"), fire, and explosions.

Occupational health factors are those system design features that serve to minimize the risk of injury, acute or chronic illness, or disability; and/or reduce job performance of personnel who operate, maintain, or support the system. Prevalent issues include noise, chemical safety, atmospheric hazards (including those associated with confined space entry and oxygen deficiency), vibration, ionizing and non-ionizing radiation, and human factors issues that can create chronic disease and discomfort such as repetitive motion diseases. Many occupational health problems, particularly noise and chemical management, overlap with environmental impacts. Human factors stresses that create risk of chronic disease and discomfort overlap with occupational health considerations.

6.2.5.2. Safety and Occupational Health Hazard Parameters/Requirements

Safety and health hazard parameters should address all activities inherent to the life cycle of the system, including test activity, operations, support, maintenance, and final demilitarization and disposal. Safety and health hazard requirements should be stated in measurable terms, whenever possible. For example, it may be appropriate to establish thresholds for the maximum level of acoustic noise, vibration, acceleration shock, blast, temperature or humidity, or impact forces etc., or "safeguards against uncontrolled variability beyond specified safe limits," where the CDD specifies the "safe limits." Safety and health hazard requirements often stem from human factor issues and are typically based on lessons learned from comparable or predecessor systems. For example, both physical dimensions and weight are critical safety requirements for the accommodation of pilots in ejection seat designs. Safety and health hazard thresholds are often justified in terms of human performance requirements, because, for example, extreme temperature and humidity can degrade job performance and lead to frequent or critical errors. Another methodology for specifying safety and health requirements is to specify the allowable level of residual risk as defined in MIL-STD-882D, for example, "There shall be no high or serious residual risks present in the system."

6.2.5.3. Safety and Occupational Health Planning

6.2.5.3.1. Programmatic Environment, Safety, and Occupational Health (ESOH) Evaluation (PESHE)

The HSI Strategy and the PESHE should jointly define how the program intends to avoid duplication of effort and to ensure the effective and efficient flow of information between the HSI and ESOH personnel working the integration of human safety and health considerations into the systems engineering process.

The related discussions of ESOH and the PESHE in the context of Systems Engineering are in Chapter 4.

6.2.5.3.2. Health Hazard Analysis (HHA)

During early stages of the acquisition process, sufficient information may not always be available to develop a complete HHA. As additional information becomes available, the initial analyses are refined and updated to identify health hazards, assess the risks, and determine how to mitigate the risks, formally accept the residual risks, and monitor the effectiveness of the mitigation measures. The health hazard risk information is documented in the PESHE. Health hazard assessments should include cost avoidance figures to support trade-off analysis. There are nine health hazard issues typically addressed in a health hazard analysis (HHA):

- Acoustical Energy. The potential energy that transmits through the air and interacts with the body to cause hearing loss or damage to internal organs.
- Biological Substances. The exposure to microorganisms, their toxins, and enzymes.
- Chemical Substances. The hazards from excessive airborne concentrations of toxic materials contracted through inhalation, ingestion, and skin or eye contract.
- Oxygen Deficiency. The displacement of atmospheric oxygen from enclosed spaces or at high altitudes.
- Radiation Energy. Ionizing: The radiation causing ionization when interfacing with living or inanimate mater. Non-ionizing: The emissions from the electromagnetic spectrum with insufficient energy to produce ionizing of molecules.
- Shock. The mechanical impulse or impact on an individual from the acceleration or deceleration of a medium.
- Temperature Extremes and Humidity. The human health effects associated with high or low temperatures, sometimes exacerbated by the use of a materiel system.
- Trauma. Physical: The impact to the eyes or body surface by a sharp or blunt object. Musculoskeletal: The effects to the system while lifting heavy objects.
- Vibration. The contact of a mechanically oscillating surface with the human body.

6.2.6. Personnel Survivability

6.2.6.1. Personnel Survivability Overview

Personnel survivability factors consist of those system design features that reduce the risk of fratricide, detection, and the probability of being attacked; and that enable the crew to withstand man-made hostile environments without aborting the mission or suffering acute chronic illness, disability, or death.

6.2.6.2. Survivability Parameters/Requirements

The CDD should include applicable crew survivability parameters. This may include requirements to eliminate significant risks of fratricide or detectability, or to be survivable in a nuclear, biological, and chemical (NBC) battlefield. NBC survivability, by definition, includes the instantaneous, cumulative, and residual effects of NBC weapons upon the system, including its personnel. It may be appropriate to require that the system “permit performance of mission-essential operations, communications, maintenance, re-supply and decontamination tasks by suitably clothed, trained, and acclimatized personnel for the survival periods and NBC environments required by the system.”

The consideration of survivability should also include system requirements to ensure the integrity of the crew compartment and rapid egress when the system is damaged or destroyed. It may be appropriate to require that the system provide for adequate emergency systems for contingency management, escape, survival, and rescue.

6.2.6.3. Personnel Survivability Planning

The JCIDS capability documents define the program’s combat performance and survivability needs. Consistent with those needs, the PM should establish a Personnel Survivability program. This program overseen by the program manage, and seeks to minimize, the probability of encountering combat threats, the severity of potential wounds and injury incurred by personnel operating or maintaining the system, and the risk of potential fratricidal incidents. To maximize effectiveness, the PM should assess Personnel Survivability in close coordination with systems engineering and test and evaluation activities.

Personnel survivability assessments assume the warfighter is integral to the system during combat. Damage to the equipment by enemy action, fratricide, or an improperly functioning component of the system can endanger the warfighter. The Personnel Survivability program should assess these events and their consequences. Once these initial determinations are made, the design of the equipment should be evaluated to determine if there are potential secondary effects on the personnel. Each management decision to accept a potential risk should be formally documented by the appropriate management level as defined in DoD Instruction 5000.2.

During early stages of the acquisition process, sufficient information may not always be available to develop a complete list of Personnel Survivability issues. Aan initial report is prepared listing those identified issues and any findings and conclusions. Classified data and findings are to be appropriately handled according to each DoD Component's guidelines. Personnel Survivability issues typically are divided into the following components:

- Reduce Fratricide. Fratricide is the unforeseen and unintentional death or injury of "friendly" personnel resulting from friendly forces employment of weapons and munitions. To avoid these types of survivability issues, personnel systems and weapon systems should include anti-fratricide systems, such as Identification of Friend or Foe (IFF) and Situational Awareness (SA) systems.
- Reduce Detectability. Reduce detectability considers a number of issues to minimize signatures and reduce the ranges of detection of friendly personnel and equipment by confounding visual, acoustic, electromagnetic, infrared/thermal, and radar signatures and methods that may be utilized by enemy equipment and personnel. Methods of reducing detectability could include camouflage, low-observable technology, smoke, countermeasures, signature distortion, training, and/or doctrine.
- Reduce Probability of Attack. Analysts should seek to reduce the probability of attack by avoiding appearing as a high value-targe; and by actively preventing or deterring attack by warning sensors and use of active countermeasures.
- Minimize Damage if Attacked. Analysts should seek to minimize damage if attacked by: 1) designing the system to protect the operators and crewmembers from enemy attacks; 2 improve tactics in the field so survivability is increased; 3) design the system to protect the crew from on-board hazards in the event of an attack (e.g., fuel, munitions, etc.); and 4) design the system to minimize the risk to supporting personnel if the system is attacked. Subject matter experts in areas such as nuclear, biological and chemical warfare, ballistics, electronic warfare, directed energy, laser hardening, medical treatment, physiology, human factors, and Information Operations can add additional issues.
- Minimize Injury. Analysts should seek to minimize: 1) combat, enemy weapon-caused injuries; 2) the combat-damaged system's potential sources and types of injury to both its crew and supported troops as it is used and maintained in the field; 3) the system's ability to prevent further injury to the fighter after being attacked; and 4) the system's

ability to support treatment and evacuation of injured personnel. Combat-caused injuries or other possible injuries are addressed in this portion of personnel survivability, along with the different perspectives on potential mechanisms for reducing damage. Evacuation capability and personal equipment needs (e.g. uniform straps to pull a crew member through a small evacuation port are addressed here.

- Minimize Physical and Mental Fatigue. Analysts should seek to minimize injuries that can be directly traced to physical or mental fatigue. These types of injuries can be traced to complex or repetitive tasks, physically taxing operations, sleep deprivation, or high stress environments.
- Survive Extreme Environments. This component is to address issues that will arise once the warfighter evacuates or is forced from a combat-affected system such as an aircraft or watercraft and must immediately survive extreme conditions encountered in the sea or air until rescued or an improved situation on land is reached. Dependent upon requirements, this may also include some extreme environmental conditions found on land, but generally this component is for sea and air where the need is immediate for special consideration to maintain an individual's life. Survival issues for downed pilots behind enemy lines should be considered here.
- The PM should summarize plans for personnel survivability in the support strategy and address personnel survivability risks and plans for risk mitigation. If the system or program has been designated by Director, Operational Test & Evaluation (DOT&E), for live fire test and evaluation (LFT&E) oversight, the PM should integrate T&E to address crew survivability issues into the LFT&E program to support the Secretary of Defense LFT&E Report to Congress (10 U.S.C. 2366). The PM should address special equipment or gear needed to sustain crew operations in the operational environment.

6.2.7. Habitability

6.2.7.1. Habitability Overview

Habitability factors are those living and working conditions that are necessary to sustain the morale, safety, health, and comfort of the user population. They directly contribute to personnel effectiveness and mission accomplishment, and often preclude recruitment and retention problems. Examples include: lighting, space, ventilation, and sanitation; noise and temperature control (i.e., heating and air conditioning); religious, medical, and food services availability; and berthing, bathing, and personal hygiene

Habitability consists of those characteristics of systems, facilities (temporary and permanent), and services necessary to satisfy personnel needs. Habitability factors are those living and working conditions that result in levels of personnel morale, safety, health, and comfort adequate to sustain maximum personnel effectiveness, support mission performance, and avoid personnel retention problems.

6.2.7.2. Habitability Parameters/Requirements

Habitability is one of several important factors included in the overall consideration of unit mission readiness. Per DoD Instruction 5000.2, the PM shall work with habitability representatives to establish requirements for the physical environment (e.g., adequate light, space, ventilation, and sanitation, and temperature and noise control) and, if appropriate, requirements for personal services (e.g., religious, medical, and mess) and living conditions (e.g., berthing and personal hygiene) if the habitability factors have a direct impact on meeting or sustaining performance requirements, sustaining mission effectiveness, or that have such an adverse impact on quality of life or morale that recruitment or retention rates could be degraded. Examples include requirements for heating and air-conditioning, noise filters, lavatories, showers, dry-cleaning and laundry.

While a system, facility, and/or service should not be designed solely around optimum habitability factors, habitability factors cannot be systematically traded-off in support of other readiness elements without eventually degrading mission performance.

6.2.7.3. Habitability Planning

PM should address habitability planning in the support strategy and identify habitability issues that could impact personnel morale, safety health, or comfort or degrade personnel performance, unit readiness, or result in recruitment or retention problems.

6.3. Human Factors Engineering (HFE)

6.3.1. Mandatory Guidance

As required by DoD Instruction 5000.2, the program manager shall employ human factors engineering to design systems that require minimal manpower; provide effective training; can be operated and maintained by users; and are suitable (habitable and safe with minimal environmental and occupational health hazards) and survivable (for both the crew and equipment).

6.3.2. Application of HFE

Human factors engineering plays an important role in each phase of the acquisition cycle, to include system definition, design, development, evaluation, and system reliability and maintainability in the field. To realize the potential of human factors engineering contributions, human factors engineering must be incorporated into the design process at the earliest stages of the acquisition process (i.e., during the Concept Refinement and Technology Development phases). The right decisions about the human-machine interfaces early in the design process will optimize human performance. Human factors engineering participation continues to each succeeding acquisition phase. The human factors engineering practitioners provide expertise that includes design criteria, analysis and modeling tools, and measurement methods that will help the program office design systems that are operationally efficient and cost-effective. In any system acquisition process, it is important to recognize the differences between the competencies (skills and knowledge) required for the various warfighters. Application of human factors engineering processes will lead to an understanding of the competencies needed for the job, and help identify if requirements for knowledge, skills, and abilities (KSAs) exceed what the user can provide and whether the deficiency will lead to a training or operational problem. Human factors engineering tools and techniques can be used to identify the KSAs of the target audience and account for different classes and levels of users and the need for various types of information products. While it is critical to understand the information processing and net-centric requirements of the system, it is equally important to understand the factors affecting format and display of the data presented to the user to avoid cognitive overload.

6.3.3. General Guidelines

Human factors engineering should be applied during development and acquisition of military systems, equipment, and facilities to integrate personnel effectively into the design of the system. A human factors engineering effort should be provided to (a) develop or improve all human interfaces of the system; (b) achieve required effectiveness of human performance during system operation, maintenance, support, control, and transport; and (c) make economical demands upon personnel resources, skills, training, and costs. The human factors engineering effort should include, but not necessarily be limited to, active participation in the following three major interrelated areas of system development.

6.3.3.1. Analysis

Starting with a mission analysis developed from a baseline scenario, the functions that must be performed by the system in achieving its mission objectives should be identified and described. These functions should be analyzed to determine their best allocation to personnel, equipment, software, or combinations thereof. Allocated functions should be further dissected to define the specific tasks that must be performed to accomplish the functions. Each task should be analyzed to determine the human performance parameters; the system, equipment, and software capabilities; and the tactical/environmental conditions under which the tasks will be conducted. Task parameters should be quantified where possible, and should be expressed in a form that permits effectiveness studies of the human-system interfaces in relation to the total system operation. Human factors engineering high-risk areas should be identified as part of the analysis. Task analysis must include maintenance and sustainment functions performed by crew and support facilities. Analyses should be updated as required to remain current with the design effort.

6.3.3.2. Design and development

Human factors engineering should be applied to the design and development of the system equipment, software, procedures, work environments, and facilities associated with the system functions requiring personnel interaction. This human factors engineering effort should convert the mission, system, and task analysis data into a detailed design and development plans to create a human-system interface that will operate within human performance capabilities, meet system functional requirements, and accomplish mission objectives.

6.3.3.3. Test and Evaluation (T&E)

Human factors engineering should be incorporated into the system test and evaluation program and integrated into engineering design and development tests, contractor demonstrations, flight tests, acceptance tests, other development tests and operational testing. Compliance with human factors engineering requirements should be tested as early as possible. Test and evaluation should include evaluation of maintenance and sustainment activities and evaluation of the dimensions and configuration of the environment relative to criteria for human factors engineering. Human factors engineering findings from design reviews, modeling, simulations, demonstrations, and other early engineering tests should be used in planning and conducting later tests. Test planning should be directed toward verifying that the system can be operated, maintained, supported, and controlled by user personnel in its intended operational environment with the intended training. Human factors engineering test planning should also consider data needed or provided by operational test and evaluation. (See sections 9.4.5. and 9.8.1.11.)

6.3.3.4. Support Strategy and Acquisition Strategy

The program manager should summarize the steps planned to be taken (e.g., contract deliverables) to ensure human factors engineering/cognitive engineering is employed during systems engineering over the life of the program to provide for effective human-machine interfaces and meet HSI requirements.

6.4. HSI Integration

The key to a successful HSI strategy is integration. To optimize total system performance and determine the most effective, efficient, and affordable design entails trade studies both within the HSI elements (manpower, personnel, training, safety and occupational health, human factors, survivability, and habitability) and between the HSI elements and the system platform (hardware and software). The program manager should integrate the system requirements for the eight HSI elements with each other, and also with the system platform. The results of these integration efforts should be reflected in updates to the requirements, objectives, and thresholds in the CDD.

In today's Joint environment, the integration across systems of systems is necessary to achieve a fully networked Joint war fighting capability. The Warfighter requires a fully networked environment and must be able to operate efficiently and effectively across the continuum of systems from initial recognition of the opportunity to engage through to mission completion. To accomplish this, HSI should be considered through system of system analysis, modeling and testing to identify opportunities for integration, synchronization, collaboration, and coordination of capabilities to meet requirements. This may require a fully integrated investment strategy with joint sponsorship from initial concept through a series of spiral or incremental developments.

Values for objectives and thresholds, and definitions for parameters contained in the capabilities documents, Manpower Estimate, Test and Evaluation Master Plan, and Acqusiition Program Baseline should be consistent. This ensures consistency and thorough integration of program interests throughout the acquisition process.

6.4.1. Integrated Product and Process Development and Integrated Product Teams

DoD acquisition policy stresses the importance of integrated product and process development (IPPD). IPPD is a management technique that integrates all acquisition activities starting with capabilities definition through systems engineering, production, fielding/deployment and operational support in order to optimize the design, manufacturing, business, and supportability processes. At the core of the IPPD are Integrated Product Teams (IPTs). HSI should be a key consideration during the formation of IPTs. (See related discussions of IPPD and IPTs at 11.8. and 10.3.) For instance, human factors engineers should be included as members of systems engineering and design teams and other IPTs that deal with human-oriented acquisition issues or topics. The training community should be included in IPTs to ensure that the operators, maintainers and support personnel are properly trained and can maintain their operational effectiveness (i.e., maintain proficiency in tasks critical to mission success) and to ensure that system users and organization/unit leaders are prepared to employ the system advantageously. The HSI community assists with IPPD as part of the Integrated Product Teams (IPTs) by ensuring that:

- HSI parameters/requirements in the ICD, CDD, and CPD are based upon and consistent with the user representative's strategic goals and strategies and are addressed throughout the acquisition process starting with technology development and continuing throughout engineering design, trade-off analysis, testing, fielding/deployment, and operational support;
- Safety and efficiency issues, identified in legacy systems and by review of design capability risks, are used to establish a preliminary hazard list (PHL) for risk management and that the issues are effectively evaluated and managed throughout the systems life-cycle at a management level consistent with the hazard;
- The factors, tools, methodologies, risk assessment/mitigations, and set of assumptions used by the acquisition community to assess manpower, personnel, and training (MPT) requirements, measure human-in-the-loop system performance, and evaluate safety, occupational health hazards, survivability, and habitability are consistent with what the functional communities/user representatives use to evaluate performance and establish performance based metrics;
- The factors used by the acquisition community to develop cost estimates are consistent with the 1) manpower and personnel requirements reported in the Manpower Estimate; 2) training requirements reported in the DoD Component training plans; and 3) assessments of safety and health hazards documented in the PESHE; and,
- The Manpower Estimates and training strategies reported during the acquisition milestone reviews are reflected in the manning documents, training plans, personnel rosters, and budget submissions when the systems are fielded.

6.4.2. HSI Strategy, Risk, and Risk Mitigation

An HSI strategy should be initiated early in the acquisition process, when the need for a new capability or improvements to an existing capability is first established. To satisfy DoD Instruction 5000.2, the PM should have a plan for HSI in place prior to entering System Development and Demonstration. The PM should describe the technical and management approach for meeting HSI parameters in the capabilities documents, and identify and provide ways to manage any HSI-related cost, schedule, or performance issues that could adversely affect program execution.

When a defense system has complex human-systems interfaces; significant manpower or training costs; personnel concerns; or safety, health hazard, habitability, or survivability issues; the PM should use the HSI plan to identify solutions. HSI risks and risk mitigation should be addressed in the acquisition strategy and PM's risk management program.

The HSI plan should address potential readiness or performance risks. For example, skill degradation can impact combat capability and readiness. The HSI plan should call for studies to identify operations that pose the highest risk of skill decay. When analysis indicates that the combat capability of the system is tied to the operator's ability to perform discrete tasks that are easily degraded (such as those contained in a set of procedures), solutions such as embedded training should be considered to address the problem. Information overload and requirements for the warfighter to dynamically integrate data from multiple sources can result in degradation of situational awareness and overall readiness. Careful consideration of common user interfaces, composable information sources, and system workload management will mitigate this risk. An on-board "performance measurements capability" can also be developed to support immediate feedback to the operators/maintainers and possibly serve as a readiness measure to the unit commander. The lack of available ranges and other training facilities, when deployed, are issues that should be addressed. The increased use of mission rehearsal, as part of mission planning, and the preparation process and alternatives supporting mission rehearsal should be addressed in the HSI plan. Team skills training and joint battle space integration training should also be considered in the HSI plan and tied to readiness.

The PM's Programmatic Environment, Safety, and Occupational Health (ESOH) Evaluation (PESHE) describes the strategy for integrating ESOH considerations into the systems engineering process and defines how PESHE is linked to the effort to integrate HSI considerations into systems engineering. The PESHE also describes how ESOH risks are managed and how ESOH and HSI efforts are integrated. It summarizes ESOH risk information (hazard identification, risk assessment, mitigation decisions, residual risk acceptance, and evaluation of mitigation effectiveness). The HSI Strategy should address the linkage between HSI and ESOH and how the program has been structured to avoid duplication of effort.

DoD Directive 5000.1 prescribes supportability to be comparable to cost, performance, and schedule in program decision-making. Program managers should establish a logistics support concept (e.g., two level, three level), training plans, and manpower and personnel concepts, that when taken together, provide for cost-effective, total, life-cycle support. MIL-HDBK-1379-1, 2, 3, & 4 may be used as a guide for Instructional Systems Development/Systems Approach to Training (ISD/SAT) and education process for the development of instructional materials. Manpower, personnel, training analyses should be tied to supportability analyses and should be addressed in the HSI plan.

Program risks related to cost, schedule, performance, supportability, and/or technology can negatively impact program affordability and supportability. The program manager should prepare a "fall-back" position to mitigate any such negative effect on HSI objectives. For example, if the proposed system design relies heavily on new technology or software to reduce operational or support manning requirements, the PM should be prepared with design alternatives to mitigate the impact of technology or software that is not available when expected.

6.4.3. HSI in the Capabilities Documents

The ICD may seek to establish a new capability, improve an existing capability, or exploit an opportunity to reduce costs or enhance performance. The ICD should describe the key boundary conditions and operational environments that impact how the system is employed to satisfy the mission need. Key boundary conditions include critical manpower, personnel, training, safety, occupational health, human factors, habitability, and personnel survivability factors that have a major impact on system performance and life-cycle costs. The DOTMLPF considerations and implications section of the ICD should discuss all relevant domains of HSI. HSI capabilities in the CDD should be specified in measurable, testable, performance-based language that is specific to the system and mission performance. A discussion of the analyses and/or results conducted to determine the HSI capabilities is not appropriate for the ICD or CDD. This information should be contained in other programmatic documentation (e.g., HSI plan, Training Systems plan, or Manpower Estimate).

6.4.4. Refining Required Capabilities

As plans for the system mature, the capabilities documents should become more specific and reflect the integration of program objectives. The PM should work with HSI analysts and user representatives to translate HSI thresholds and objectives in the capabilities documents into quantifiable and measurable system requirements. The PM should refine and integrate operational and design requirements so they result in the proper balance between performance and cost, and keep programs affordable. Additionally, system requirements should serve as the basis for developing engineering specifications, and should be reflected in the statement of work (SOW), contracts, Test and Evaluation Master Plan, and other program documentation. Over the course of the acquisition process, as trade-offs are made and plans for the system design mature, the capabilities documents should be updated to reflect a more refined and integrated set of parameters.

6.4.5. HSI throughout the System Life Cycle

6.4.5.1. Research and Development, Studies, and Analyses in Support of HSI

Continuous application of human-centered research data, methods, and tools will ensure maximum operational and training effectiveness of the system. Continual analysis of system functionality provides data to help determine the best allocation of tasks to personnel, hardware, or software. Results guide human workload predictions, man-machine interface requirements, and procedural, software, and hardware innovations needed to ensure that the human element can fulfill and enhance total system performance. Each military department conducts human factors engineering research. The products of this research form the basis for creating and maintaining human factors engineering military standards, design criteria, methodologies, tools, and data bases used when applying human factors engineering to defense systems acquisition. Within each military department, human factors engineering practitioners support ongoing concepts and studies that identify potential human factors engineering impacts on operational effectiveness and resource needs of alternative solutions. Examples of these activities include field assessments, human performance modeling, simulations, and technology demonstrations.

6.4.5.2. Technology Development and System Development and Demonstration

The purpose of the TD and SDD phases is to develop a system or an increment of capability; reduce integration and manufacturing risk (technology risk reduction occurs during Technology Development); ensure operational supportability with particular attention to reducing the logistic footprint; implement HSI; design for producibility; ensure affordability and protection of critical program information (CPI) by implementing appropriate techniques such as anti-tamper; and demonstrate system integration, interoperability, safety and utility.

6.4.5.2.1. Systems Engineering

Once parameters are established in the ICD and CDD, it is the PM's responsibility to ensure that they are addressed during the systems engineering process and properly considered during cost/performance trade-off analyses. Consistent with section E1.29 of DoD Directive 5000.1, the PM shall apply HSI to optimize total system performance operational effectiveness, suitability, survivability, safety, and affordability. PMs shall consider supportability, life cycle costs, performance, and schedule comparable in making program decisions. As required by DoD Instruction 5000.2, the PM shall take steps (e.g., contract deliverables and

Government/contractor IPT teams) to ensure human factors engineering/cognitive engineering is employed during systems engineering from the initial concept phase through the life of the program to provide for effective human-machine interfaces, meet HSI requirements, and (as appropriate) support a system-of-system acquisition approach. The PM shall also ensure that HSI requirements are included in performance specifications and test criteria. MPT functional representatives, as user representatives, participate in the systems engineering process to help produce the proper balance between system performance and cost and to ensure that requirements remain at affordable levels. Manpower, personnel, training, and supportability analyses should be conducted as an integral part of the systems engineering process, beginning with concept refinement and continuing throughout program development.

6.4.5.2.1.1. System Design

Human factors engineers play a major role in the design process. Front-end analysis methods, such as those described in MIL-HDBK-46855A, should be pursued to maximize the effectiveness of the new system. Initial emphasis should be placed on "lessons learned" from predecessor or comparable systems to help identify and eliminate characteristics in the new system that require excessive cognitive, physical, or sensory skills or high aptitudes; involve complex fault location or workload intensive tasks; necessitate excessive training; require proficiency training; or result in frequent or critical errors or safety/health hazards. Placing an emphasis on the "human-in-the-loop" ensures that systems are designed to operate consistent with human performance capabilities and limitations, meet system functional requirements, and fulfill mission goals with the least possible demands on manpower, personnel, and training. Moreover, human factors engineers minimize added costs that result when systems have to be modified after they are fielded in order to correct performance and safety issues.

6.4.5.2.1.2. Functional Analysis and Allocations

During systems engineering, functional analysis should be performed iteratively to define successively lower functional and performance requirements, to identify functional interfaces, and to allocate functions to components of the system (e.g., hardware, software, and human). Tasks should be allocated to the human component consistent with human attributes (i.e., capabilities and limitations) of the user population as established in the Target Audience Description (TAD). Requirements analysis should be conducted iteratively in conjunction with functional analysis to develop and refine system level performance requirements, identify external interfaces, and provide traceability among user requirements and design requirements. Human-machine interfaces should be identified as an outgrowth of the functional allocation process. Another product of the systems engineering process is a list of job tasks with performance/confidence levels. This information is used to further refine manpower, personnel and training requirements.

6.4.5.2.2. Specifications and Standards

It is primarily the responsibility of the PM, with the assistance of the IPTs, to establish performance specifications, design criteria standards, interface standards, and data specification in the solicitation and resulting contract. Strong consideration should be given to establishing standards when uniform configuration is necessary for ease of operation, safety, or training purposes. For instance, a control panel or avionics suite may need to be standardized to enhance the ability of the user to access information and to respond quickly in an emergency situation.

Standard features preclude the need to teach multiple (or conflicting) responses to similar tasks. Standardization is particularly important when a standard performance is required for safety reasons. For instance, rapid ejection from the cockpit should require standard procedures and tasks. If there are unique health hazard or survivability requirements, such as vibration or shock tolerances, extended temperature range, or noise levels, standardization may be the most efficient way to ensure that the system meets those special requirements. Preference should be given to specifications and standards developed under the Defense Standardization Program. Regulatory occupational exposure standards create performance thresholds. However, use of guidance exposure criteria and ergonomic/HSI guidelines should be considered to ensure personnel protection, promote efficiency, and anticipate more stringent standards that are likely to be required during the life-cycle of the system.

Performance standards for operators, maintainers, both individual and team, are derived from the performance requirements of the total system. For example, human performance requirements (e.g., completion times or success rates) presumes that in order for the total system to achieve specified performance levels, the human will have to complete tasks or achieve performance objectives within specified confidence levels (usually expressed in terms of per cent of actions completed within a specified time-frame and/or error limit). The training/instructional system should be developed to ensure that operators can meet or exceed the personnel performance levels required to operate/maintain the systems. Additionally, manpower should be determined based on these same performance requirements. Operational tests should also be based on the same criteria.

6.4.5.2.3. Solicitations and Source Selection

HSI considerations must be clearly defined and given proper weight in solicitations and proposal evaluation guidelines provided to the government evaluation team. The record of contractors in safety and implementation of human engineering can be an element of bid selection and contract performance criteria.

6.4.5.3. Production and Deployment

The objective of this phase of the acquisition process is to achieve an operational capability that satisfies mission needs. Operational test and evaluation shall determine the effectiveness and suitability of the system.

6.4.5.4. Operations and Support (O&S)

The objective of this phase is the execution of a support program that meets operational support performance requirements and sustains the system in the most cost-effective manner over its life-cycle. As required by section E1.19 (need link) of DoD Directive 5000.1, planning for O&S shall begin as early as possible in the acquisition process. Efforts during the O&S phase should be directed towards ensuring that the program meets and has the resources to sustain the threshold values of all support performance requirements. Once the system is fielded or deployed, a follow-on operational testing program, to assess performance, quality, compatibility, and interoperability, and identify deficiencies, should be conducted, as appropriate. Post fielding verification of the manpower, and information resulting from training exercises, readiness reports, and audits can also be used to assess the operational capability of the system. During fielding, deployment, and throughout operational support, the need for modifications to the system should be assessed.

6.5. Affordability

Consistent with DoD Directive 5000.1, all participants in the acquisition system shall recognize the reality of fiscal constraints. The user shall address affordability when establishing capability needs and at each milestone decision point. As required by DoD Instruction 5000.2, the affordability of the system is determined during the requirements process and is included in each CDD using life-cycle cost or, if available, total ownership cost. Transition into the System Development and Demonstration (SDD) phase requires full funding (i.e., inclusion of the dollars and manpower needed for all current and future efforts to carry out the acquisition strategy in the budget and out-year program) which shall be programmed when a system concept and design have been selected. In the case of a replacement system, when the Milestone B is projected to occur in the first two years of the Future Years Defense Program under review, the program shall be fully funded in that Planning, Programming, and Budget Execution process cycle. In no case shall full funding be provided later than Milestone B, unless a program first enters the acquisition process at Milestone C. (See section 3.2.)

6.5.1. Life-Cycle Cost Objectives

As required by DoD Directive 5000.1, the estimation of ownership costs shall begin as early as possible in the acquisition process. Life-cycle cost objectives are usually established prior to program initiation. These objectives embody the planned affordability for the program. At each subsequent milestone review, the MDA assesses life-cycle cost objectives and progress towards achieving (see DoD Instruction 5000.2).

The O&S portion of the life-cycle costs should be consistent with manpower, personnel, and training constraints established in the CDD.

6.5.2. Manpower Estimates

Manpower Estimates shall address manpower affordability in terms of military end strength (including force structure and student end strength) and civilian work years beginning at Milestone B. Consistent with DoD Directive 5000.1, DoD Components shall plan programs based on realistic projections of the dollars and manpower likely to be available in future years. When major manpower increases are required to support the program, or major manpower shortfalls exist, they shall be identified as risks in the Manpower Estimate, and addressed in the risk assessment section of the Acquisition Strategy. Program risks that result from manpower shortfalls should be addressed in terms of their impact on readiness, operational availability, or reduced combat capability.

6.5.3. Cost as an Independent Variable

DoD Directive 5000.1 requires the PM to view cost as an independent variable. During trade-off analysis, PMs should consider whether it is more cost effective for the Department to spend additional money during the engineering and design process to achieve a system with reduced support costs than it is to design a more resource intensive system at reduced acquisition costs. Such comparisons should consider all aspects of life-cycle costs, including mishaps resulting in lost work time.

6.6. Additional References

6.6.1. DoD Publications

The following DoD Directives and Instructions provide manpower, personnel, and training policy and direction:

- DoD Directive 1100.4, "Guidance for Manpower Programs"
- DoD Directive 1100.9, "Military-Civilian Staffing of Management Positions in Support Activities"
- DoD Directive 1100.18, "Wartime Manpower Mobilization Planning"
- DoD Directive 1322.18, "Military Training"
- DoD Directive 1430.13, "Training Simulators and Devices"
- DoD Instruction 1322.20, "Development and Management of Interactive Courseware for Military Training"
- Training Transformation Implementation Plan June 2004

6.6.2. Discretionary Practices

The following military standards (MIL-STD), DoD Handbooks (DOD-HDBK), and Military handbooks (MIL-HDBK) may be used to support HSI analysis:

- MIL-STD-882D, Standard Practice for System Safety
- MIL-STD-1472, DoD Design Criteria Standard: Human Engineering
- MIL-STD-1474, Noise Limits for Military Materiel
- MIL-STD-1477, Symbols for Army Air Defense System Displays
- MIL-STD-1787, Aircraft Display Symbology
- MIL-STD-1801-Human Engineering Requirements for User/Computer Interface
- DOD-HDBK-743, Anthropometry of US Military Personnel
- DOD-HDBK-761, Human Engineering Guidelines for Management Information Systems
- MIL-HDBK-759, Human Engineering Design Guidelines
- MIL-HDBK-1379-1, Guidance for Acquisition of Training Data Products and Services
- MIL-HDBK-1379-2, Instructional Systems Development/Systems Approach to Training and Education
- MIL-HDBK-1379-3, Development of Interactive Multimedia Instruction
- MIL-HDBK-1379-4, Glossary of Training Terms
- MIL-HDBK-1473-Color and Marking of Army Materiel
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- MIL-HDBK-1908, Definitions of Human Factors Terms
- MIL-HDBK-46855A-Human Engineering Program Process and Procedures
- MILPRF 29612, Performance Specification, Training Data Products "A Guide for Early Embedded Training Decisions," US Army Research Institute for the Behavioral and Social Sciences Research Product 96-06.